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F/N Ratio and the Effect of Systematics on the 1e20 POT CC Analysis

J. Thomas, P. Vahle
University College London
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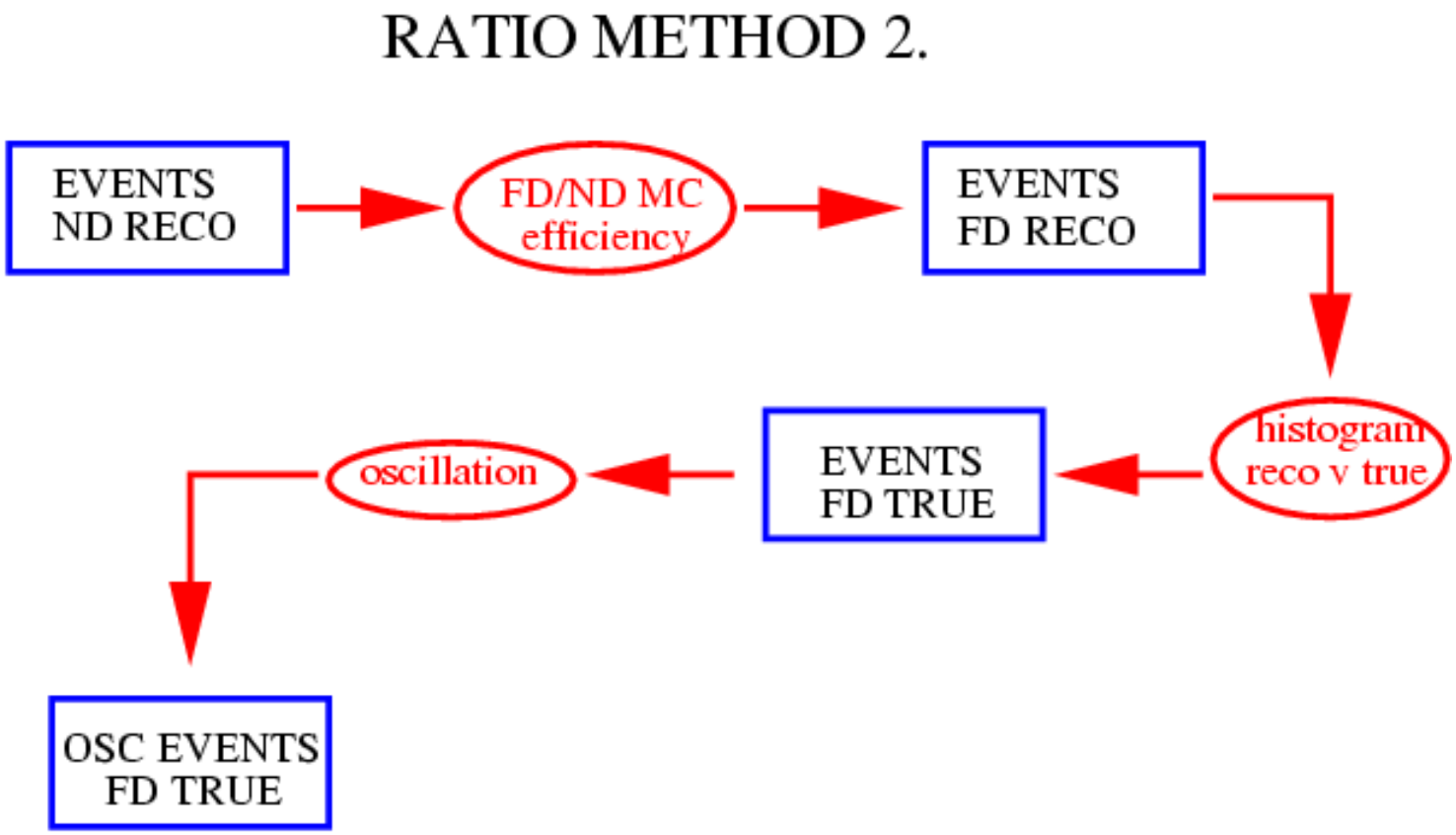
Outline:

I. **The Ratio Method+Fitter**
II. **Updated MDC Results**
III. **Updated Contours and Pseudo experiments**
IV. **The Systematics studied**
V. **Updated Results**
VI. **Conclusions**

Introduction

- Using the F/N ratio, we predict the FD spectrum, then use this prediction to fit a modified MC set that has been oscillated with given parameters
- Modifications simulate different systematics
- Compare with fits to standard MC to see effect of systematic
- Using R1.18.2 LE10 MC for this study

The Ratio Method



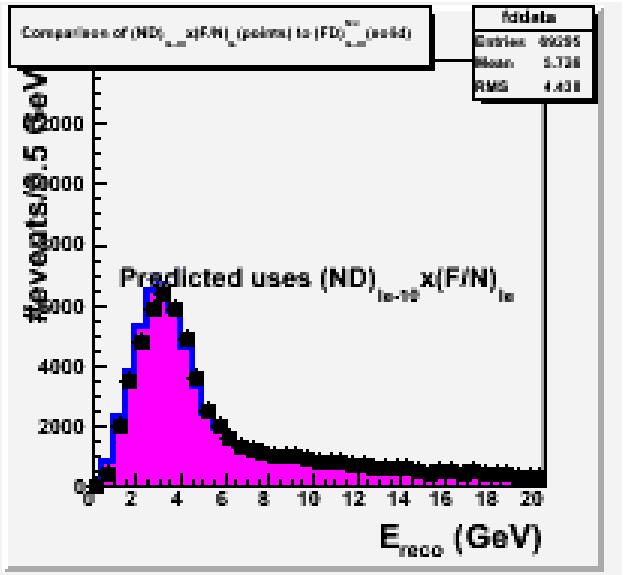
- Now using F/N ratio in reconstructed energy
- Avoids one extra reco vs. true transformation in ND

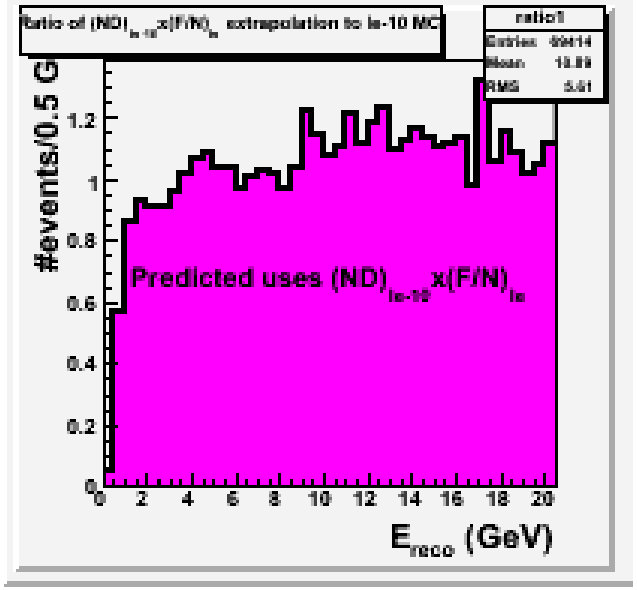
Cuts

Comparing 4 different event selection techniques:

- Preselection
  - "Accepted" Fid. Vol in both detectors
  - Ntrack>0
  - Pass_track==1
  - Litime==-1 (FD)
  - Event doesn't start or end on crate boundary (FD)
- TV—preselection plus:
  - Consistent uv vertex
  - If curvy, error in (q/p)/(q/p)<0.3
  - 90% of shower in fully instrumented region (ND)
  - Charge <0
  - Track z vertex>0.6m
  - No other event within 50ns
- DP—preselction plus:
  - Dave pid>-0.1 in near, -0.2 in far
  - Dircosneu>0.6
- NS—preselection plus:
  - Niki pid<0.2 in near, 0.25 in far
  - Dircosneu>0.6

Ratio Performance





FD Reco E_ν

- **Black—prediction of LE10 FD Reco E_ν spectrum using F/N from LE MC**
- **Pink—Real LE10 FD Reco E_ν spectrum**

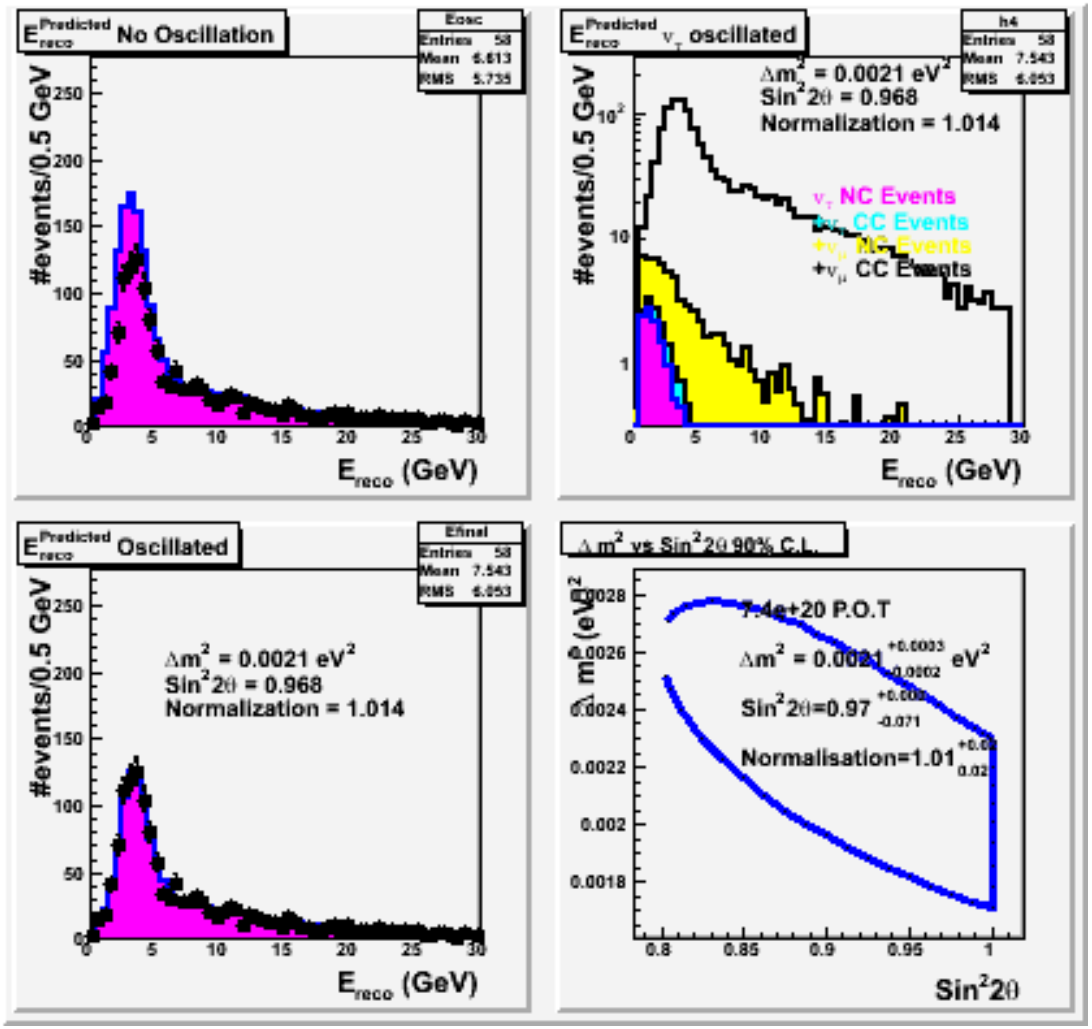
Ratio Predicted/Real LE10

Fitting

- Uses Miniuit
- Maximize Log Likelihood between data and ratio predicted FD spectrum by varying osc. parameters and oscillating FD predicted spectrum
- 3 parameters included
  - dm^2
  - $\sin^2(2\theta)$
  - overall normalization—with a 4% penalty term

Updated MDC Results

With penalty term for normalization



Our Results:

Δm^2=0.0021±0.0003 eV^2
$\sin^2(2\theta)$=0.97+/-0.07
Norm=1.01+/-0.02

Dave's Results:

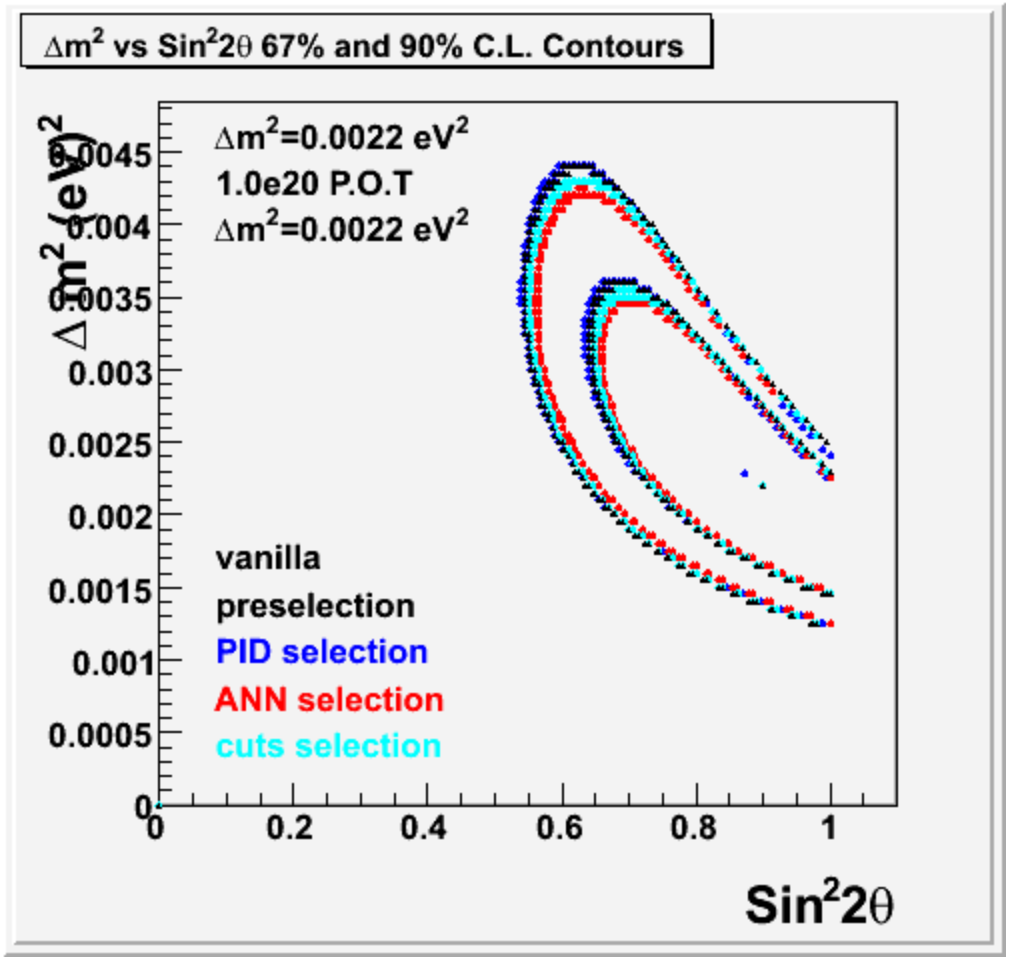
Δm^2=0.002175 eV^2
$\sin^2(2\theta)$=0.925

Truth:

Δm^2=0.002123 eV^2
$\sin^2(2\theta)$=0.881

Sensitivity, no systematics

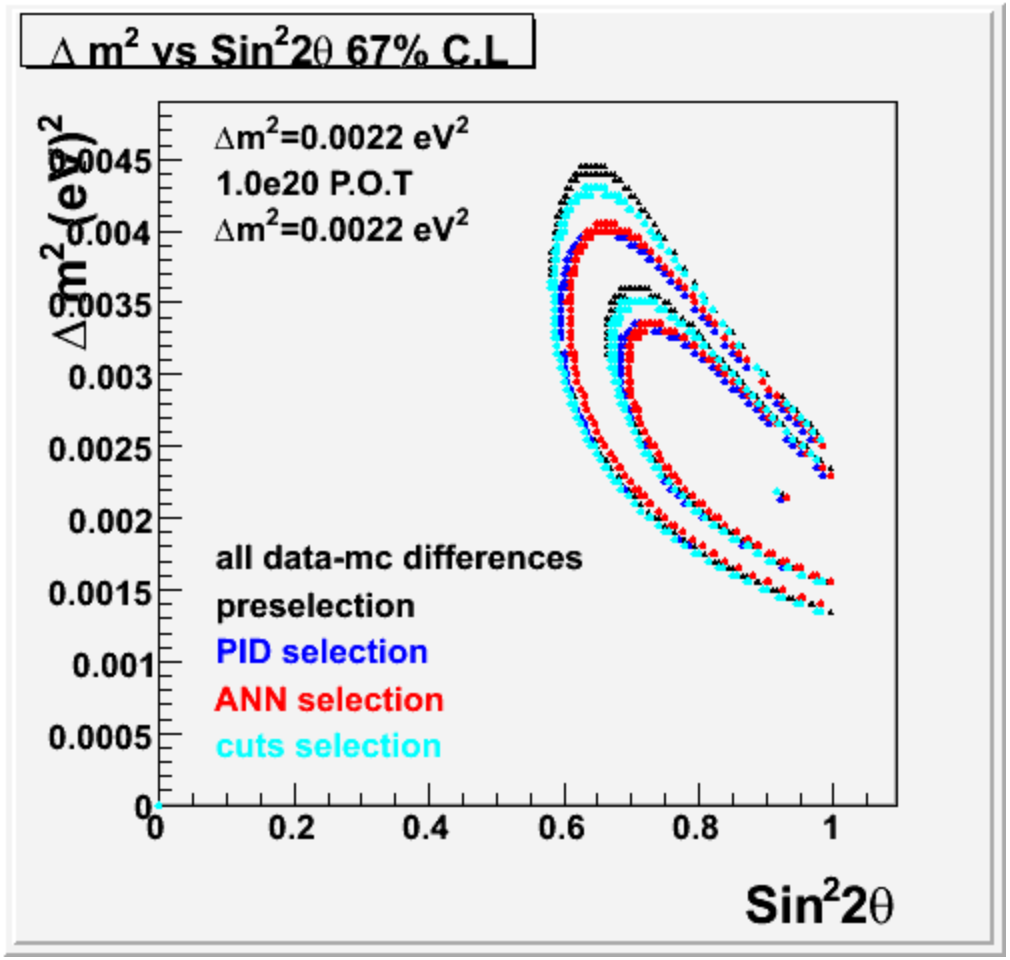
For Four different selection techniques



Fit MC against MC

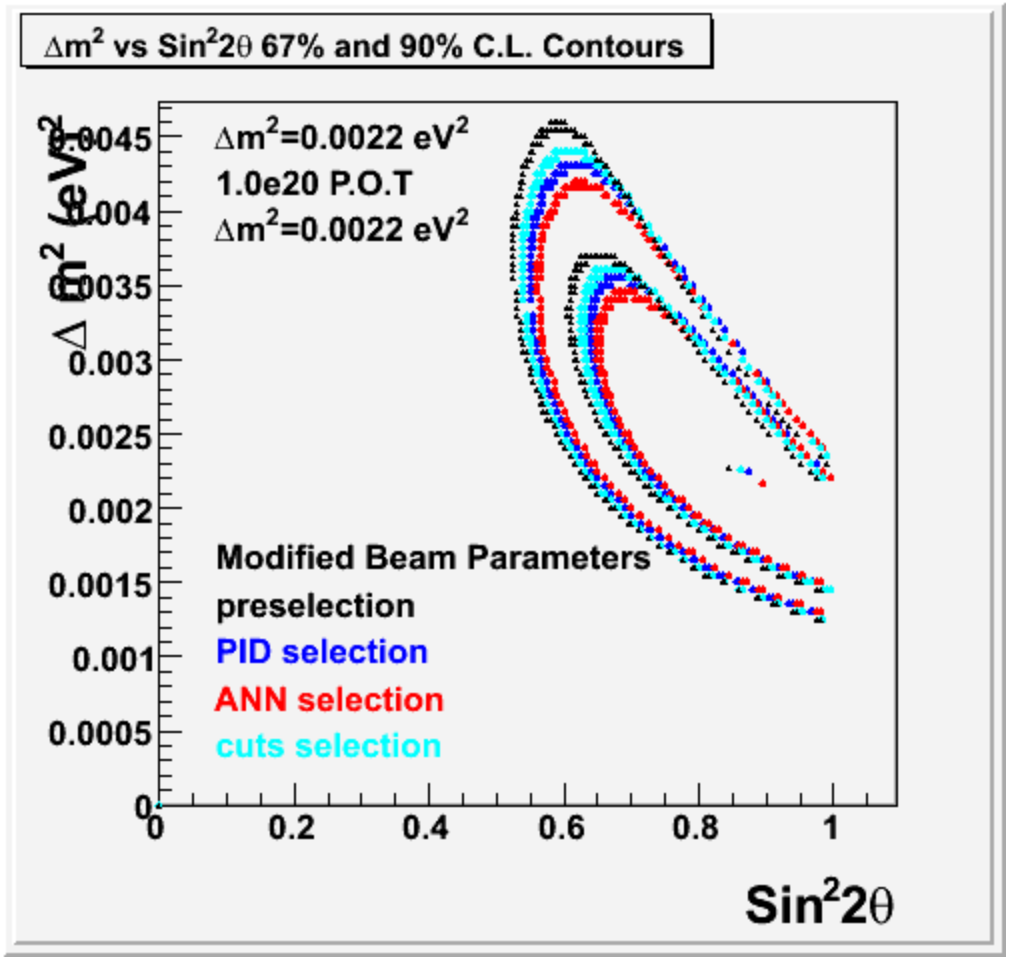
Sensitivity

For Four different selection techniques
Take all the difference between data/MC—propagate it incorrectly to FD



Sensitivity

For Four different selection techniques
F/N modulated by hadron production reweighting



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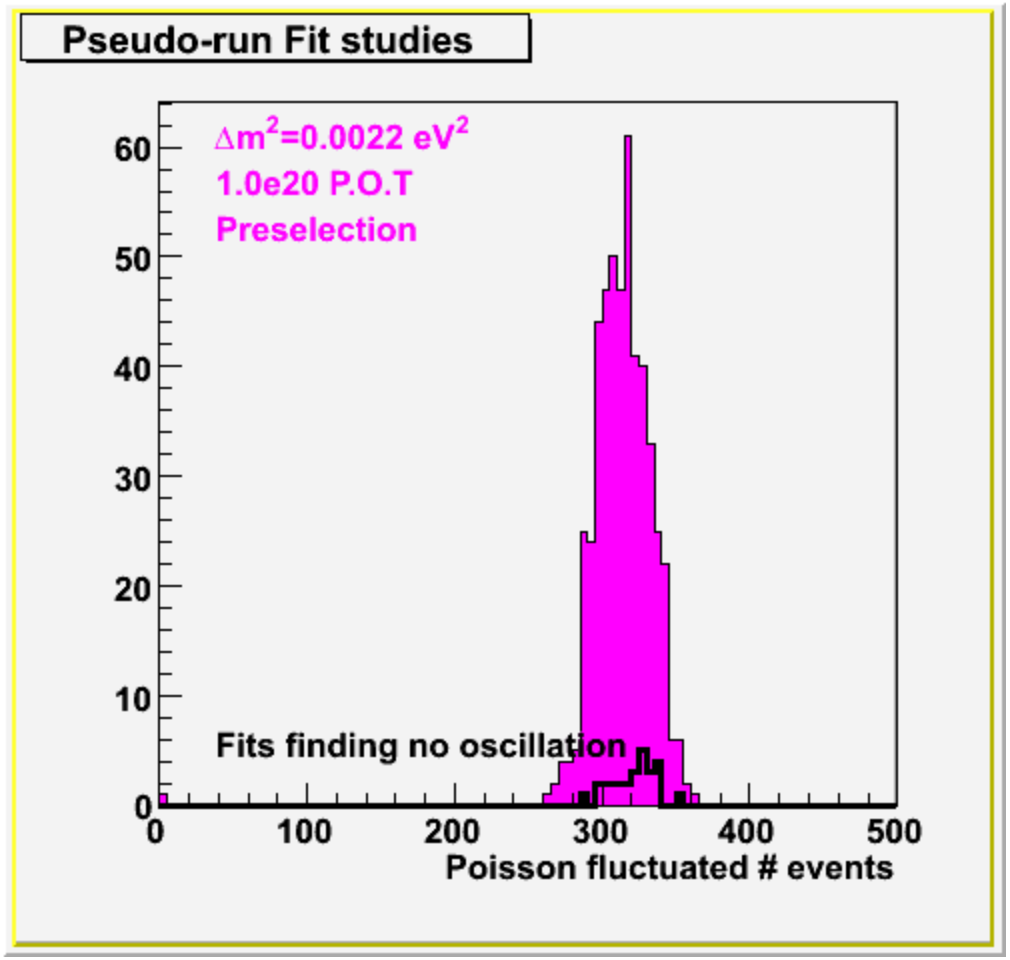
Pseudo experiment —Fake Data Generation

- Modify MC sample to include effects of systematic (described later)
- Oscillate
- NOW, fluctuate total number of expected events by poisson, select that many events from total oscillated spectrum
  - Previous fluctuations allowed larger excursions in the total number of events than expected

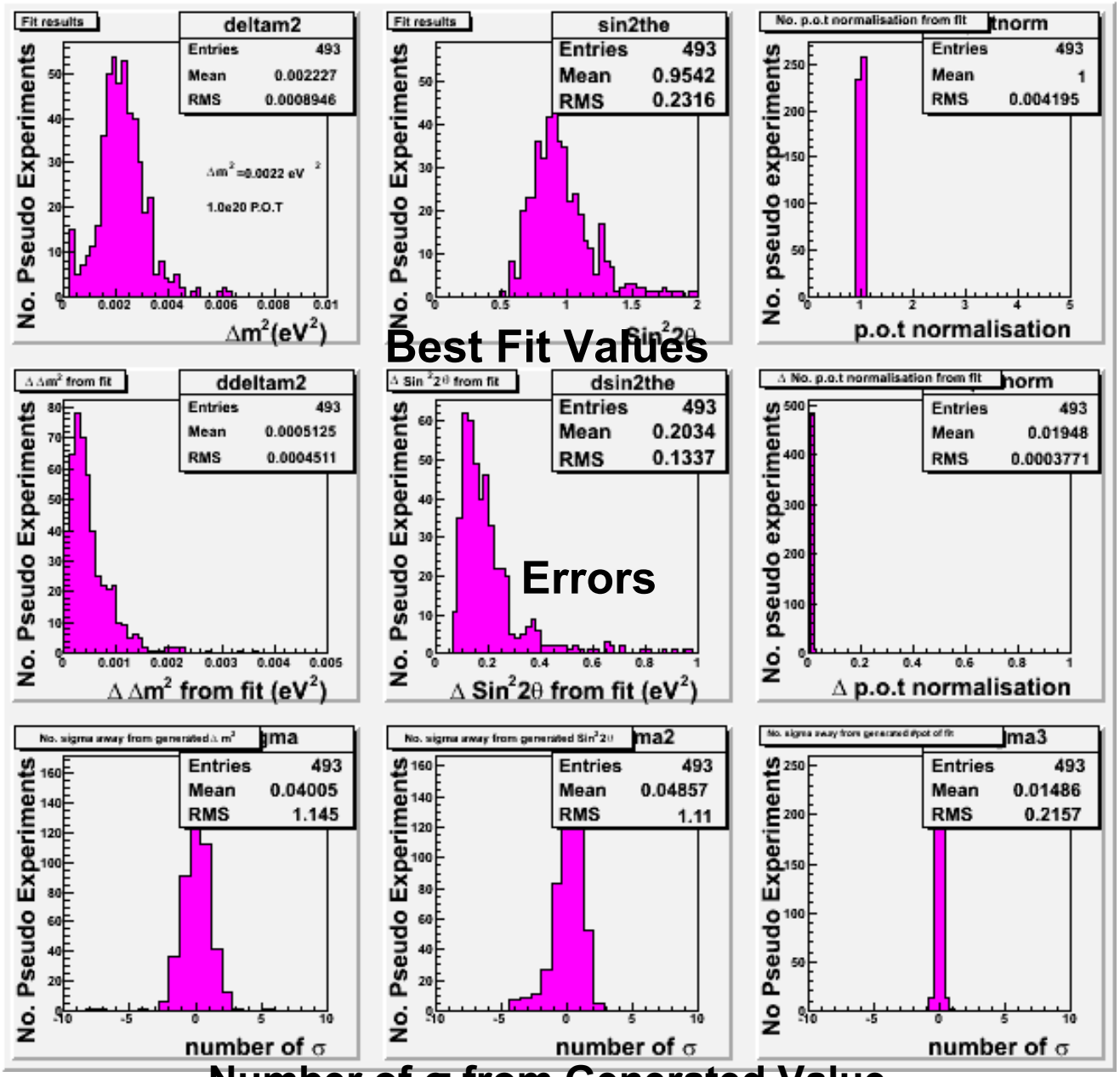
A look at fluctuations

Number of events in each pseudo-experiment



Preselection only

Δm^2 | $\sin^2(2\theta)$ | Norm



Number of σ from Generated Value

Summary of Pseudo runs

- No Systematics
- Fit MC against MC
- Generated Values
  - Δm^2=0.0022 eV^2
  - $\sin^2(2\theta)$=0.9
  - 1e20 POT
- 500 pseudo runs
- 493 converge
- on average
  - Δm^2 .04σ
  - $\sin^2(2\theta)$ .05σ
  - norm .01σ

Investigating failures & Biases

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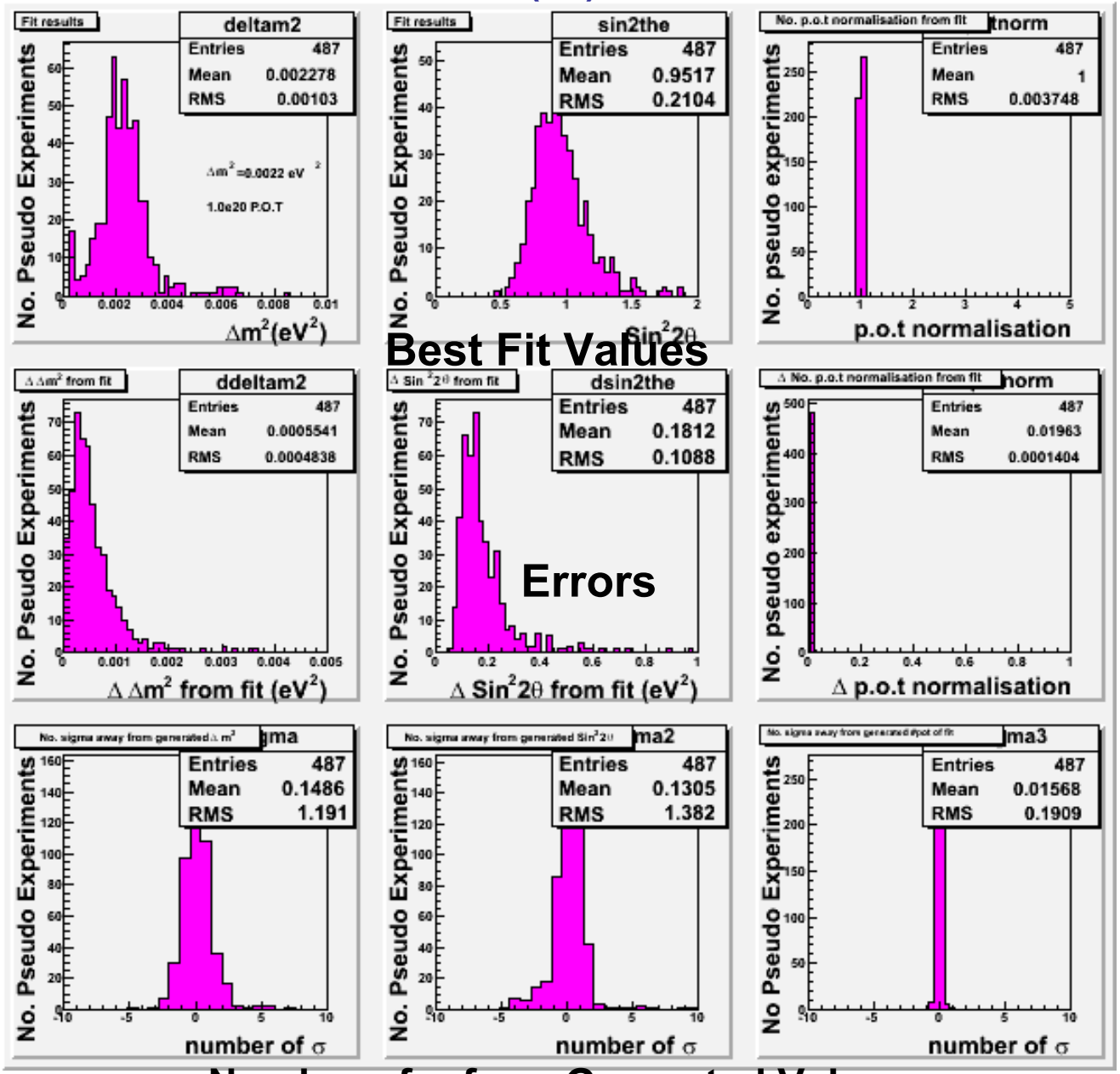
- **Why did fits fail at Oxford?**
  - **Fixing the way of generating the fake data helped**
  - **A few 10's of fits still fail the first time**
    - **Can be recovered by refitting with $\sin^2(2\theta)<4$**
  - **7 pseudo runs do not converge now**
- **Why the bias**
  - **We were cutting out runs with $\sin^2(2\theta)>2$, these also cut out low Δm^2, biasing that distribution high**
  - **Mean best fit of $\sin^2(2\theta)$ still tends to be higher than generated value, though pull function mean is close to zero**

TV PID

Δm^2 $\sin^2(2\theta)$ Norm



Best Fit Values

Errors

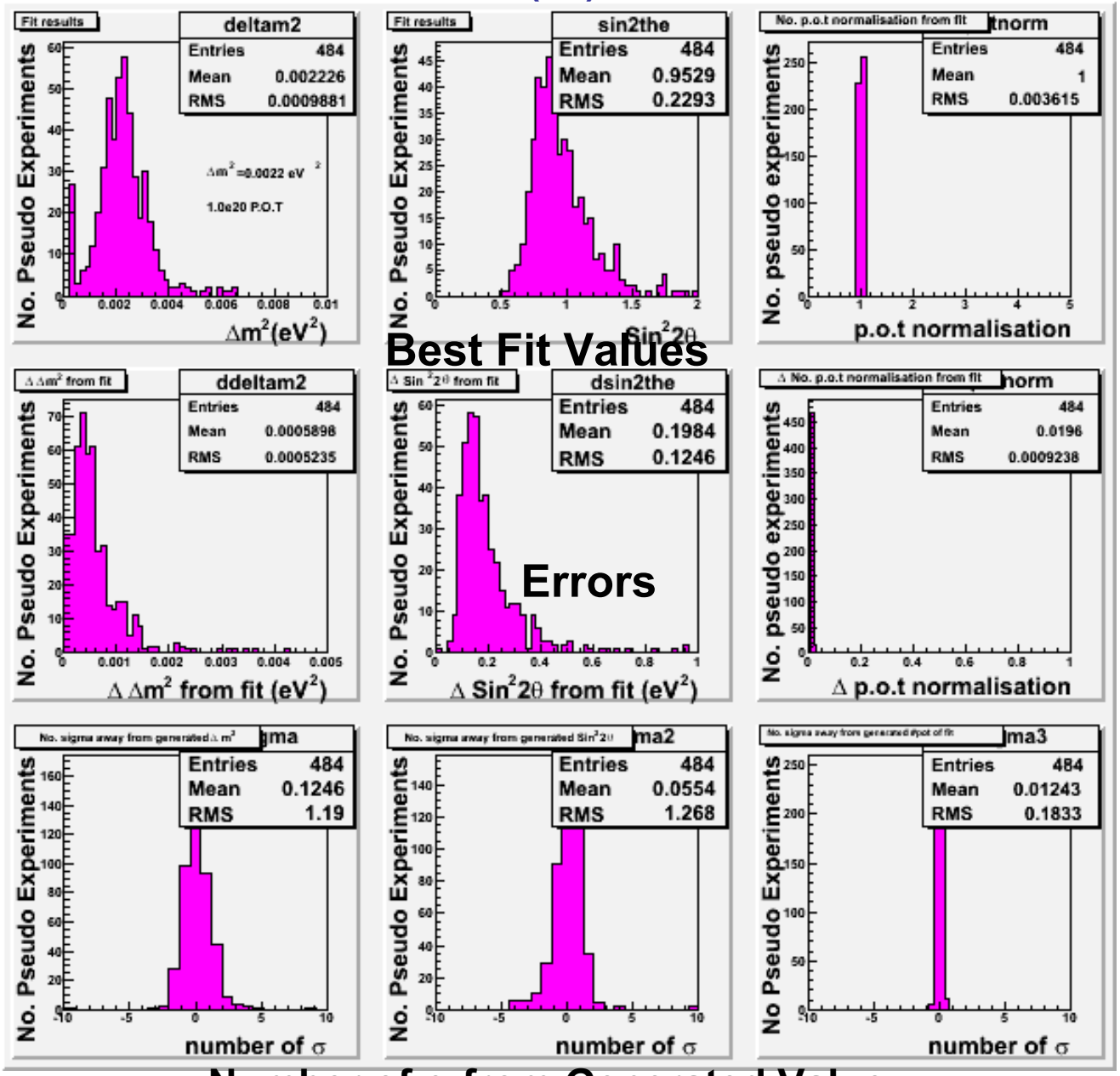
Number of σ from Generated Value

Summary of Pseudo runs

- No Systematics
- Fit MC against MC
- Generated Values
  - $\Delta m^2=0.0022$ eV^2
  - $\sin^2(2\theta)=0.9$
  - 1e20 POT
- 500 pseudo runs
- 487 fits converge
- on average
  - Δm^2 .15σ
  - $\sin^2(2\theta)$ .13σ
  - norm .02σ
- Used to be:
  - 310 fits converge
  - Δm^2 .404σ
  - $\sin^2(2\theta)$ .056σ
  - norm .464σ

DP PID

Δm^2 $\sin^2(2\theta)$ Norm



Best Fit Values

Errors

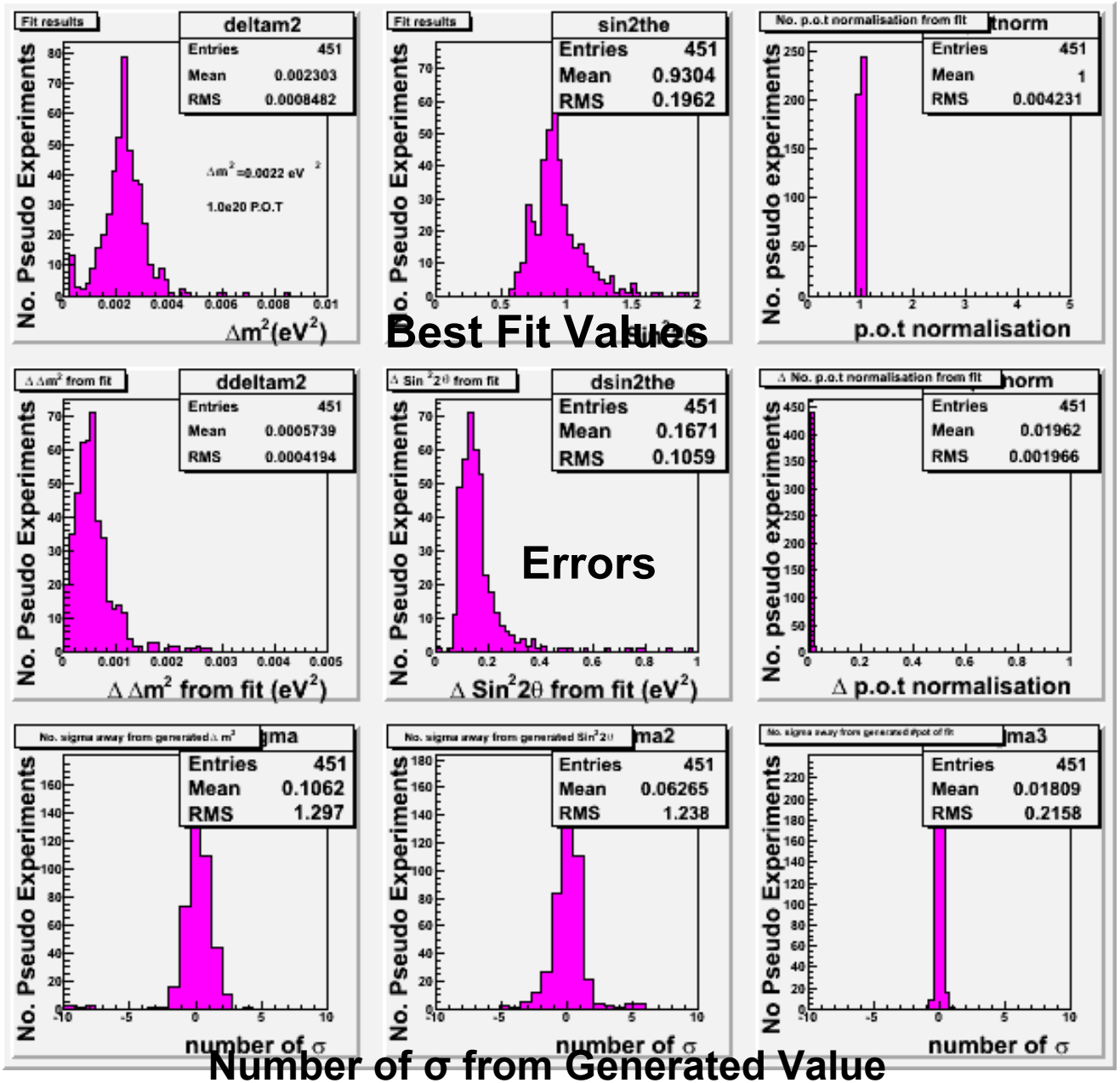
Number of σ from Generated Value

Summary of Pseudo runs

- No Systematics
- Fit MC against MC
- Generated Values
  - $\Delta m^2 = 0.0022\ eV^2$
  - $\sin^2(2\theta) = 0.9$
  - 1e20 POT
- 500 pseudo runs
- 484 fits converge
- on average
  - Δm^2 .12σ
  - $\sin^2(2\theta)$ .05σ
  - norm .01σ

NS PID

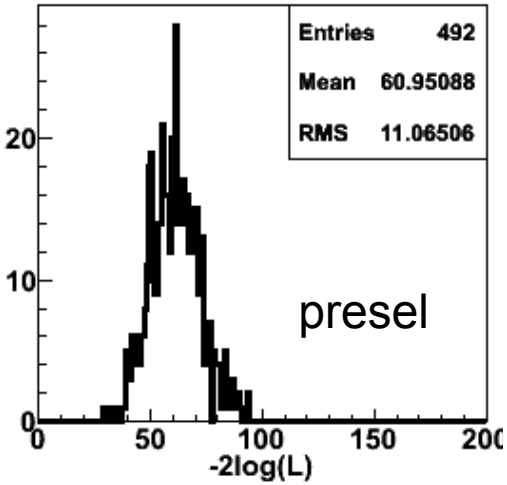
Δm^2 $\sin^2(2\theta)$ Norm

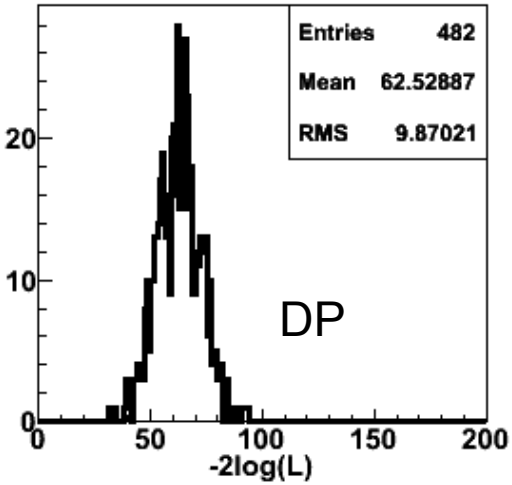


Summary of Pseudo runs

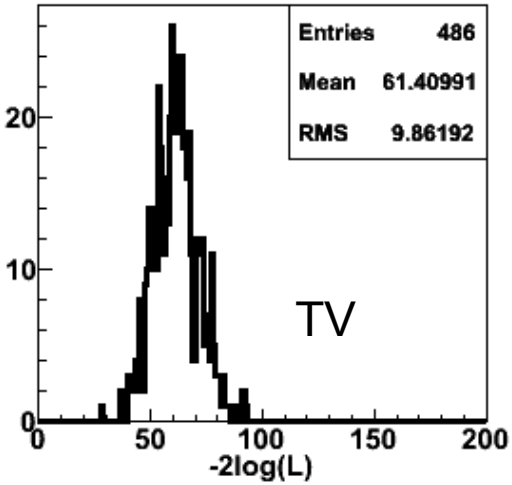
- No Systematics
- Fit MC against MC
- Generated Values
  - Δm^2=0.0022 eV^2
  - $\sin^2(2\theta)$=0.9
  - 1e20 POT
- 500 pseudo runs
- 451 fits converge
- on average
  - Δm^2 .11σ
  - $\sin^2(2\theta)$ .06σ
  - norm .01σ

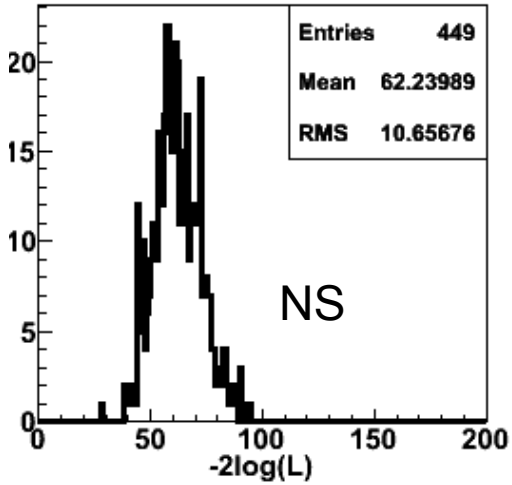
Log Likelihood distribution





56 degrees of freedom





Systematic Studies

- **Cross section parameter variations**
  - increase ma_qe, ma_res and both to 50%
  - Kno parameters increase by 20%
- **Intranuke**
  - increase shower energy in both det. by 10%
- **Relative Calibration Errors**
  - change total reco E_ν to 80%,90%,95%,105%,110% and 120%
- **Different Flux Predictions**
  - reweighted fake data to different fluxes, i.e. LE10, LE10 170kA, etc.
- **POT Normalization Errors**
  - rescaled to 90% and 110% of known POTs
- **NC Contamination**
  - Doubled the neutral current contamination
- **"Unknown" differences**
  - increased number of events in first 7 bins of ND spectrum by 10%, no change to FD spectrum
  - used LE10 ND REAL data to predict FD spectrum, but drew fake data from std. LE FD MC
- **All generator uncertainties changed together**
- **All generator and intranuke**
- **All generator, intranuke and 95% miscalibration**
- **F/N ratios from hadron reweighting studies**

blue=new study
Red=not yet redone

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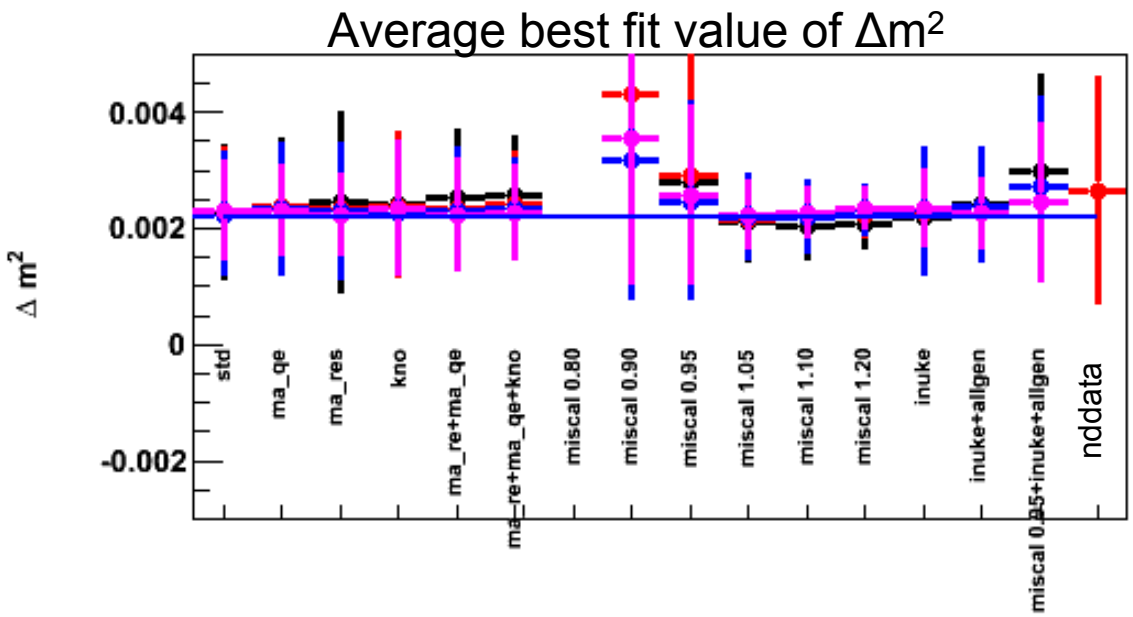
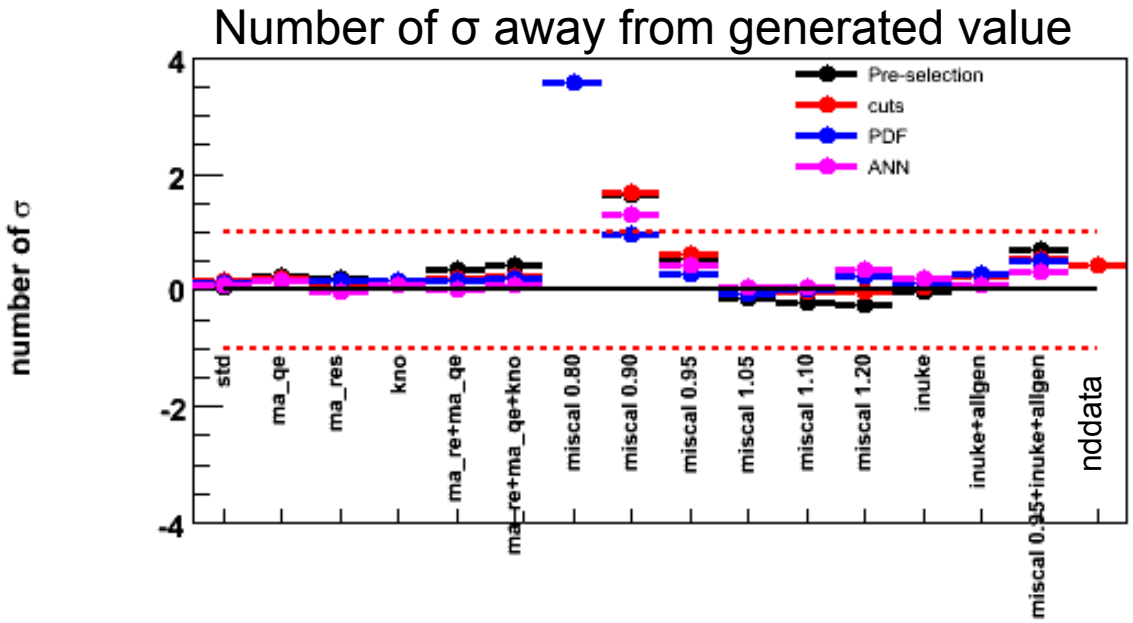
Δm^2 Summary





Generated Values

- **Δm^2=0.0022 eV^2**
- **sin^2(2θ)=0.9**
- **1e20 POT**

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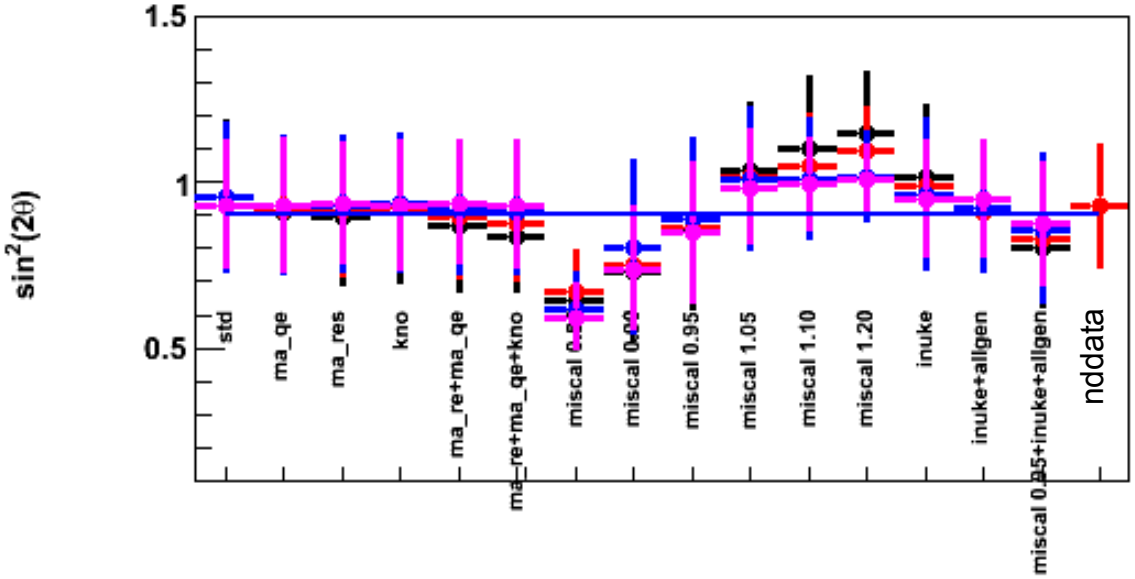
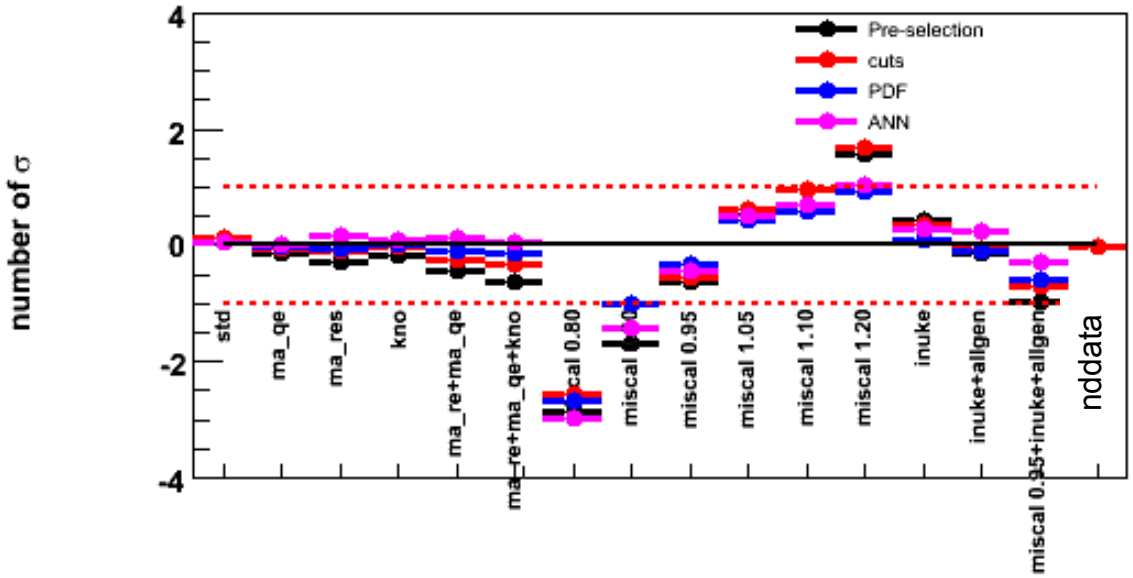
$\sin^2(2\theta)$ Summary

Average best fit value of $\sin^2(2\theta)$



Number of σ away from generated value



Generated Values

- **Δm^2=0.0022 eV^2**
- **$\sin^2(2\theta)$=0.9**
- **1e20 POT**

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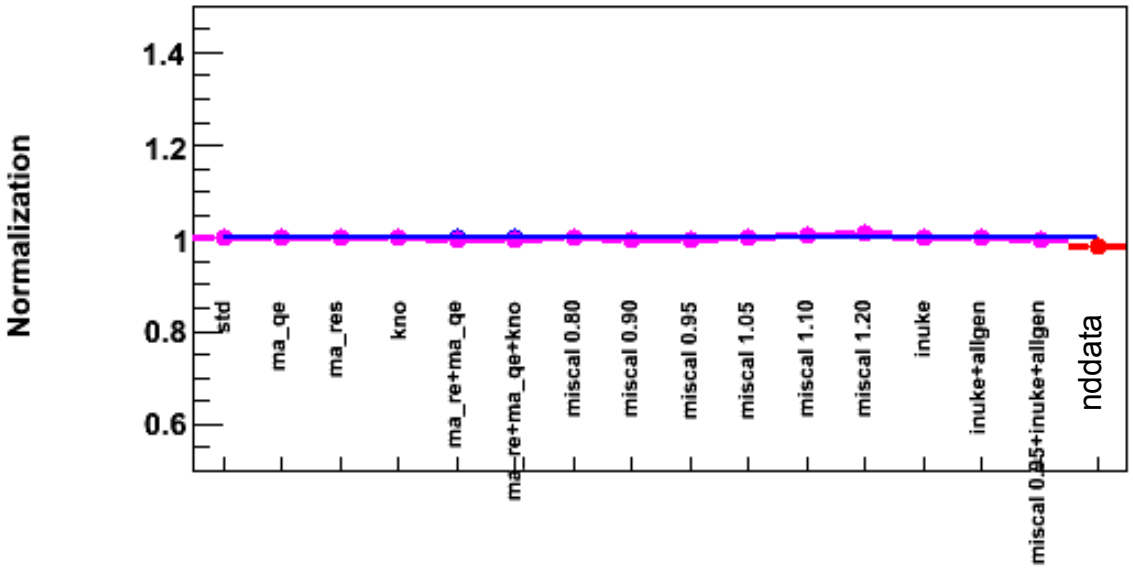
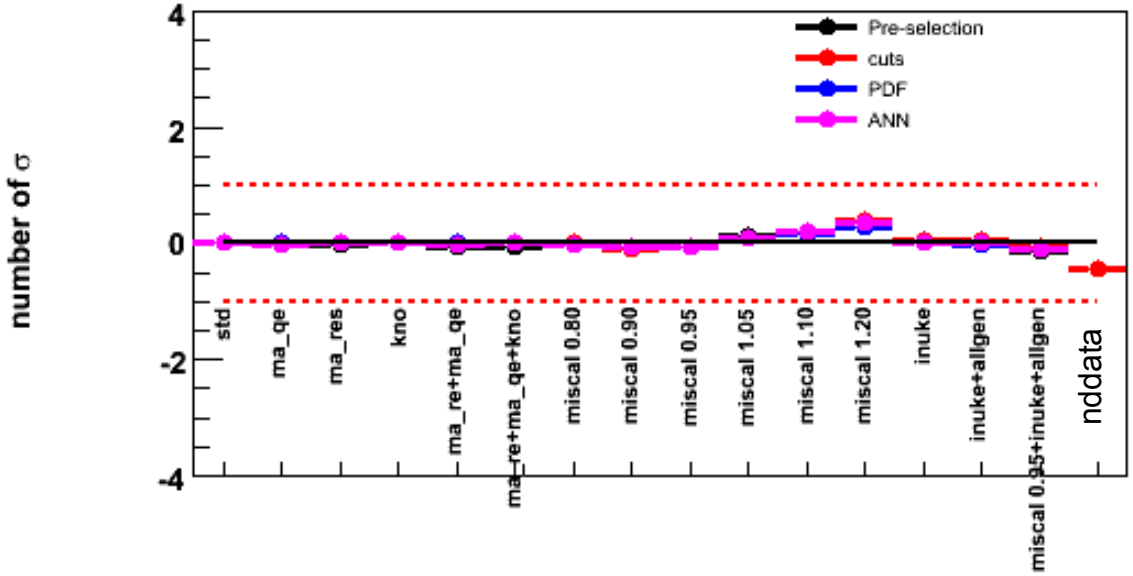
Normalization Summary

Average best fit value of normalization



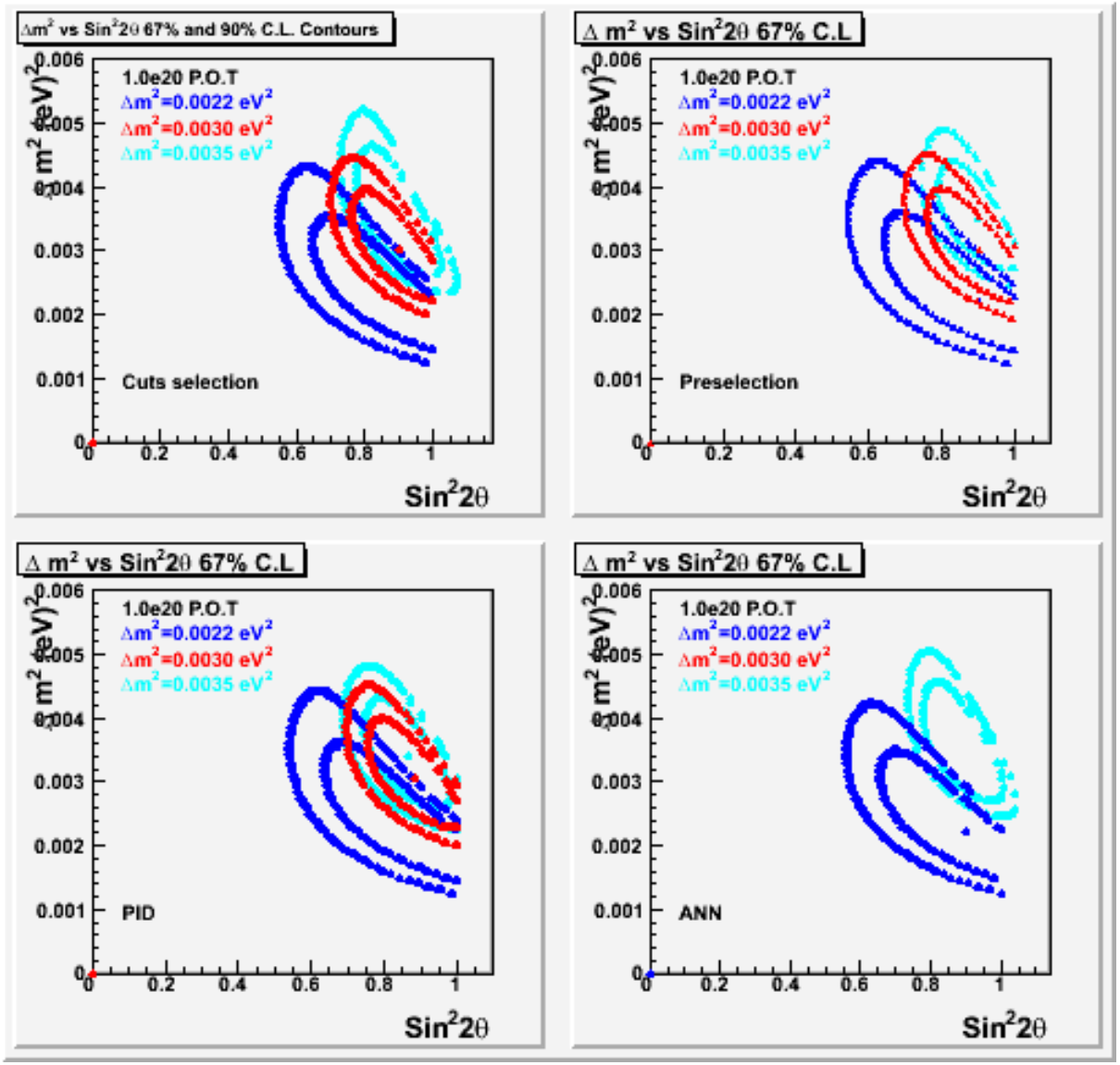
Number of σ away from generated value



Generated Values

- **$\Delta m^2 = 0.0022\ eV^2$**
- **$\sin^2(2\theta) = 0.9$**
- **1e20 POT**

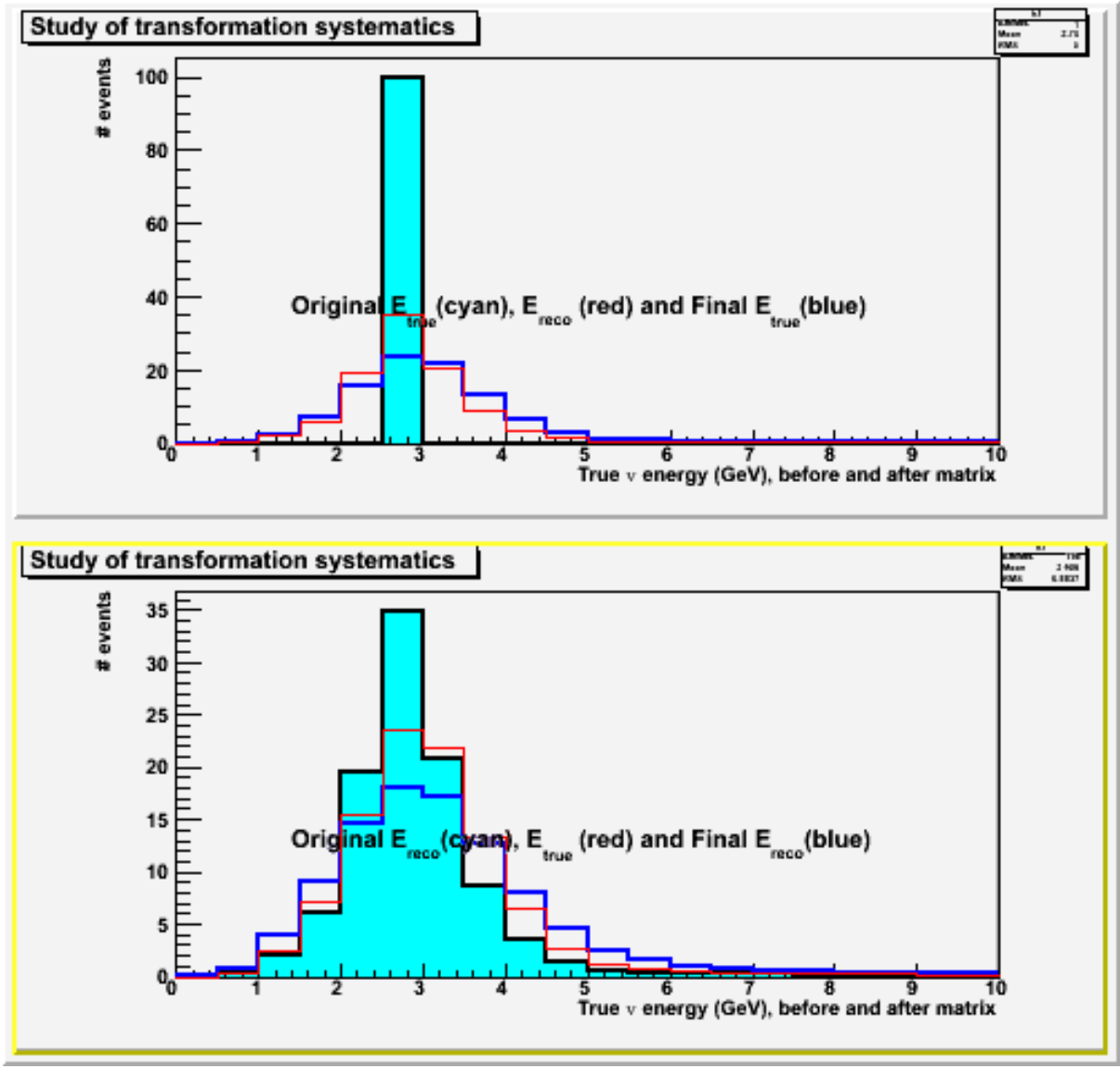
Different delta m2's



Conclusions

- Significantly improved since Oxford
- Looked into different event selection techniques
- Looked at the effect of sources of systematic errors on the best fit errors (using pseudoruns)
  - For 1e20, even large variations in many areas do not cause significant perturbation in the parameter measurement
  - Miscalibrations causing relative differences in total neutrino energy must be kept at the 5% level.
- Robust and simple procedure for measuring oscillation parameters.

backup


Study of transformation systematics
events
Original E_true (cyan), E_reco (red) and Final E_true (blue)
True ν energy (GeV), before and after matrix
Study of transformation systematics
events
Original E_reco (cyan), E_true (red) and Final E_reco (blue)
True ν energy (GeV), before and after matrix